

**PORTLAND HARBOR RI/FS**  
**DRAFT FINAL REMEDIAL INVESTIGATION REPORT**  
**ATTACHMENT F3:**  
**RISKS FROM EXPOSURES TO PBDES**

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## **2.01.0 INTRODUCTION**

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This Attachment F3 presents ~~the Lower Willamette Group's (LWG's)~~an evaluation of risks to human health from polybrominated diphenyl ethers (PBDEs) in the Portland Harbor Superfund Site (Site) in Portland, Oregon, ~~which is being performed at the direction of the United States Environmental Protection Agency (EPA).~~ This Attachment is intended to supplement the Revised Baseline Human Health Risk Assessment (BHHRA) for the Site. The objectives and approach to assessing risks from exposures to PBDEs follows those outlined in the BHHRA.

## **3.02.0 PBDE DATA EVALUATION**

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The data included in the site characterization and risk assessment (SCRA) dataset are described in detail in Section 2 of the RI Report. The dataset used in this human health risk analysis for PBDEs is a subset of the data that comprised the SCRA dataset as of February 2011. All data included in the BHHRA PBDE dataset meets the data quality requirements for risk evaluation (Category 1/QA2), as agreed to between LWG, EPA, and EPA's partners in the Programmatic Work Plan (Integral et al. 2004). As directed by EPA, in-water sediment and fish tissue samples collected in 2004 and 2007 from the Portland Harbor that were analyzed for PBDE congeners and met the data criteria for inclusion in the BHHRA were used in this evaluation. Data management and reduction rules applied to the BHHRA PBDE dataset are the same as those described in Attachment F2.

### **3.12.1 IN-WATER SEDIMENT**

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In-water surface sediment PBDE data used in the BHHRA includes LWG- collected data from sampling rounds 2 and 3. These sampling events include:

- Round 2A sediment grabs
- Round 3 sediment from upstream and downstream
- Round 3B Biota - Co-located sediments
- Round 3B sediment grabs

These sampling events comprise 59 samples used in the BHHRA PBDE dataset, 51 of which are within the Study Area. The BHHRA PBDE dataset for in-water sediment is consistent with the criteria described in the data evaluation section of the BHHRA (Section 2 of Appendix F).

### **3.22.2 FISH TISSUE**

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Common carp and smallmouth bass fish tissue were collected by the LWG from within Portland Harbor in 2007 and analyzed by the EPA in 2009. The fish tissue samples were analyzed as composite samples, fillets with skin included. The remainder tissue of the common carp and smallmouth bass samples were also analyzed. For each analytical result, whole body concentrations were calculated based on a weighted average of fillet tissue and remainder tissue concentrations, as described in Attachment F2, and consistent with data handling for the rest of the BHHRA.

The BHHRA PBDE dataset consists of 18 smallmouth bass samples collected from RM 1.5 to 11.5, and 9 common carp tissue samples collected from RM 0 - 12.

### **3.32.3 SHELLFISH TISSUE**

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Shellfish tissue in the PBDE dataset included clam (*Corbicula* sp.) tissue collected during the Round 3B biota sampling event. All clam samples analyzed for PBDEs were undepurated. There were four samples collected within the Study Area (river mile (RM) 1.9 – 11.8), one sample collected from the downstream reach (RM 1.5), and one sample collected in the downtown reach (RM 12.1). All six of these sample results were included in the BHHRA PBDE dataset for clam tissue.

### **3.42.4 IDENTIFICATION OF CONTAMINANTS OF CONCERN**

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In-water sediment and tissue samples were analytes for eight different PBDE congeners, as follows:

- BDE 028 (2,4,4'-Tribromodiphenyl ether)
- BDE 047 (2,2',4,4'-Tetrabromodiphenyl ether)
- BDE 099 (2,2',4,4',5-Pentabromodiphenyl ether)
- BDE 100 (2,2',4,4',6-Pentabromodiphenyl ether)
- BDE 153 (2,2',4,4',5,5'-Hexabromodiphenyl ether)
- BDE 154 (2,2',4,4',5,6'-Hexabromodiphenyl ether)
- BDE 183 (2,2',3,4,4',5,6'-Heptabromodiphenyl ether)
- BDE 209 (2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether)

All detected PBDE congeners were retained as contaminants of potential concern (COPCs) for each medium and species. PBDE congeners analyzed and detected in in-water sediment are BDE 47, 99, 153, and 209. PBDE congeners analyzed and detected in carp tissue are BDE 28, 47, 100, 153, and 154. PBDE congeners analyzed and detected in smallmouth bass tissue are BDE 28, 47, 99, 100, 153, and 154, and 183. In



clam tissue, detected congeners are BDE 47, 99, 100, 153, and 154. BDE 209 was not detected in fish or shellfish tissue.

#### **4.03.0 EXPOSURE ASSESSMENT**

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PBDE risk assessment was performed for potentially exposed human populations that may come in contact with PBDEs in in-water sediment or tissue.

The exposure assessment performed for PBDEs is consistent with the exposure assessment performed in Section 3 of the BHHRA. As described in Section 3 of Appendix F, potentially exposed human populations identified for further evaluation for exposure to PBDEs are:

- In-water worker
- Diver
- Fisher (Fish consumer)
- Tribal fisher
- Infants exposed to human breast milk of the above populations

Exposure pathways were identified using the same methods described in Section 3 of the BHHRA. The potential exposure pathways to human populations at the Study Area include:

- Ingestion of and dermal contact with in-water sediment
- Ingestion of fish and shellfish
- Infant consumption of human milk

The identified receptors, exposure routes, and exposure pathways, and the rationale for selection are also summarized in Table 3-1 of Appendix F.

#### **4.13.1 CALCULATION OF EXPOSURE POINT CONCENTRATIONS**

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Exposure point concentrations (EPCs) were calculated for media and pathways that were evaluated quantitatively in this Attachment. The process to estimate EPCs for tissue and in-water sediment is the same as the process followed in Section 3 of the BHHRA. Individual PBDE congeners were evaluated for adult and child receptors. Risks to infants were evaluated as total PBDEs to be consistent with Oregon Department of Environmental Quality (DEQ) guidance (DEQ 2010). PBDE EPCs for exposure to in-water sediment are presented in Table F3-1. PBDE EPCs for exposure to tissue are presented in Tables F3-2 to F3-7.

#### **4.23.2 PROCESS TO CALCULATE INTAKES**

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Intakes were calculated in the manner described in Section 3 of the BHHRA. The BHHRA presents population-specific assumptions for the evaluated receptors. Values used for intake parameters for the evaluation of risks from PBDEs are the same as those used in the BHHRA, and are presented in Table 3-27 (for receptors exposed to PBDEs in in-water sediment) and Table 3-29 (for receptors exposed to PBDEs in tissue) of Appendix F.

#### **5.04.0 TOXICITY ASSESSMENT**

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This quantitative evaluation of noncancer hazards and cancer risks included the four PBDE congeners for which the EPA has established human health toxicity values in the Integrated Risk Information System (IRIS) database: BDE 47, BDE 99, BDE 153, and BDE 209. The EPA has established oral reference doses for the congeners BDE 47, BDE 99, BDE 153, and BDE 209. BDE 209 is the only congener analyzed that is classified as a carcinogen. PBDE congeners without carcinogenic toxicity values were not evaluated for cancer risk. Table F3-8 presents the toxicity values for the PBDE congeners that were quantitatively evaluated.

#### **6.05.0 RISK CHARACTERIZATION**

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The risk characterization for exposure to PBDEs in in-water sediment and tissue was performed as described in Section 5 of Appendix F. Noncancer hazards and cancer risks to children and adults were calculated for individual congeners at each exposure point, and then summed to provide cumulative hazards and cancer risk estimates. Noncancer hazards and cancer risks to breast-feeding infants were calculated based on cumulative hazards and cancer risks to adult mothers by applying a PBDE-specific infant risk adjustment factor (IRAF), consistent with DEQ guidance (DEQ 2010).

#### **6.15.1 RISK AND HAZARD RESULTS**

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##### **6.1-15.1.1 Direct Contact with In-Water Sediment Risk Characterization Results**

Potential risks from exposure to PBDEs in in-water sediment through incidental ingestion and dermal absorption were estimated for the in-water workers, tribal fishers, high- and low-frequency fishers, and divers, for both reasonable maximum exposure (RME) and central tendency (CT) scenarios. Risks and hazards from exposures to PBDEs in in-water sediment are presented in Tables F3-9 through F3-19.

Cancer risks from exposure to PBDEs in in-water sediment were orders of magnitude below the EPA target risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ . Cancer risks for all receptors and exposure scenarios ranged from  $2 \times 10^{-15}$  for the CT exposure for a low-frequency fisher and diver in wet suit at RM 9.5 east, to  $9 \times 10^{-11}$  for the RME scenario for a tribal fisher at RM 8 west.

Hazards from exposure to PBDEs in in-water sediment were orders of magnitude below the EPA target hazard quotient (HQ) of 1. Cumulative HQs per exposure area ranged from  $1 \times 10^{-8}$  for the CT exposures for a low-frequency fisher and diver in wet suit at RM 1.5 west to a high of  $4 \times 10^{-5}$  for tribal fishers at RM 3.5 east.

#### **6.1.25.1.2 Fish Tissue Consumption Risk Characterization Results**

Potential risks from exposure to PBDEs in fish tissue through ~~ingestion~~ consumption were estimated for adult and child consumers of fish, for both fillet tissue and whole body ~~tissue~~ diets ~~consisting exclusively~~ of smallmouth bass or common carp. ~~Both 95 percent upper confidence levels on the mean (95% UCL) or maximum exposures and mean exposures were assessed at three different ingestion rates, using the methodology as~~ described in Section 5 of Appendix F. Hazards from exposures to PBDEs in tissue are presented in Tables F3-20 through F3-27.

Cancer risks were not calculated for ~~tissue ingestion scenarios~~ fish consumption because the carcinogenic PBDE congener was not detected in the tissue samples evaluated.

HQs from exposure to PBDEs in smallmouth bass and common carp tissue ranged from  ~~$9 \times 10^{-2}$~~  0.09 to 4, which is above the EPA target HQ of 1, over the ingestion rates, tissue types, and EPCs that were evaluated. The highest HQ occurred at RM 4 from the consumption of smallmouth bass whole body tissue ~~by assuming a childhood consumption at the rate~~ 60 g/day ingestion rate using exposure point concentrations equaling the maximum detected concentrations for the exposure area (due to limited sample size, as described in Section 3 of Appendix F). HQs were ~~above greater than~~ 1 for adult consumption of carp and smallmouth bass ~~only at the assuming a~~ 142 g/day consumption rate and for child consumption of carp and smallmouth bass at ~~both~~ the 60 g/day and 31 g/day consumption rates.

In general, hazards from consuming whole body tissue were greater than risks from consuming fillet tissue. Hazards from ~~ingestion-consumption~~ of smallmouth bass whole body tissue are comparable to those from ingestion of common carp whole body tissue, but hazards from ingestion of smallmouth bass fillet tissue are approximately an order of magnitude lower than hazards from ingestion of common carp fillet tissue. Hazards from ingestion of either whole body smallmouth bass or common carp at a specified ingestion rate are within a factor of approximately two throughout the entire Study Area.

### **6.1.35.1.3 Shellfish Tissue Risk Characterization Results**

Potential risks from exposure to PBDEs in shellfish tissue through ingestion were estimated for adult consumers of clam, for undepurated tissue analyzed as whole body without shell. ~~Both 95% UCL/Reasonable Maximum maximum exposures and mean exposures were assessed at two different ingestion rates,~~ as described in Section 5 of Appendix F. Hazards from exposures to PBDEs in tissue are presented in Tables F3-28 and F3-29.

Cancer risks were not calculated for consumption of shellfish ~~ingestion scenarios~~ because carcinogenic PBDE congeners were not detected in the tissue samples collected.

Hazards from exposure to PBDEs in clam tissue ~~were below the EPA target HQ less than of 1~~ for all scenarios evaluated. ~~Cumulative HQs per exposure area ranged from  $4 \times 10^{-3}$  to  $4 \times 10^{-2}$ .~~

### **6.1.45.1.4 Infant Breastmilk Consumption Risk Characterization Results**

The results of the infant breastmilk consumption pathway are presented for the breast-feeding infant of an adult receptor for each of the exposure scenarios previously discussed. Consistent with DEQ guidance (DEQ 2010) and based on an agreement with EPA, an IRAF was calculated for total PBDEs and applied to cumulative cancer risk and noncancer hazard estimates for each adult exposure scenario and exposure area. The cancer IRAF for total PBDEs is 0.5, and the noncancer IRAF for total PBDEs is 38. Cancer risks and hazards to an infant based on exposure to PBDEs from breastmilk consumption from the adult mothers described in the previous exposure scenarios are presented in Tables F3-30 through F3-46.

A cancer IRAF of 0.5 means that cancer risks to a breastfeeding infant from exposures to PBDEs would be half of the cancer risks from PBDE exposures to the nursing mother. The maximum cancer risk to an infant from consumption of PBDEs in breastmilk would be approximately  $5 \times 10^{-11}$ , due to breastfeeding from a mother who is a tribal fisher exposed to in-water sediment. ~~This is orders of magnitude below the EPA target cancer risk of  $1 \times 10^{-6}$ .~~ Cancer risks were not calculated for an infant breastfeeding from an adult fish or shellfish consumer because carcinogenic PBDE congeners were not detected in the tissue samples collected.

A noncancer IRAF of 38 for total PBDEs means that hazards to an infant from exposures to PBDEs in breast milk are 38 times greater than hazards to the mother from PBDE exposures. The maximum HQ for an infant from exposure to PBDEs in breastmilk is approximately 80, due to exposures to a mother who is a consumer of whole body smallmouth bass from RM 4 at a consumption rate of 142 g/day. There are no hazards ~~exceeding an greater than a~~ HQ of 1 to a breastfeeding infant whose

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mother is exposed to in-water sediment or to PBDEs through consumption of clams consumption.

#### **6.4.55.1.5 Summary of Risk Characterization**

Hazards and cancer risks from exposures to PBDEs were evaluated for adult, child and infant receptors from exposures to in-water sediment and tissue.

This risk evaluation shows that there are ~~no all estimated~~ cancer risks ~~exceeding the EPA target risk level of~~ are less than  $1 \times 10^{-6}$  for ~~any all~~ of the scenarios evaluated.

Hazards from exposures to PBDEs in in-water sediment are ~~below~~ less the EPA target HQ of 1.

~~Hazards from ingestion of PBDEs in fish tissue exceed the EPA target HQ of 1 for both adult and child consumers at some ingestion rates. The highest HQ from fish consumption is four times higher than the EPA target HQ.~~

Hazards from exposures to PBDEs in shellfish are below the EPA target HQ of 1.

Hazards and cancer risks to an infant from ingestion of PBDEs in breast milk of a mother exposed to in-water sediment are below EPA target hazard and cancer risk levels. Hazards to an infant breastfeeding from an adult consumer of smallmouth bass or carp ~~are 38 times higher than hazards to the mother from that ingestion route; the hazards to the infant of an adult fish consumer exceed~~ are greater than the EPA target HQs for all ~~ingestion consumption~~ rates and exposure levels.

### **7.06.0 UNCERTAINTY ANALYSIS**

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The uncertainties associated with this evaluation of risks from exposures to PBDEs are the same uncertainties associated with the BHHRA methods discussed in Section 6 of the RI/FS Appendix F. This section emphasizes the uncertainties specific to the PBDE dataset.

#### ***Limited number of PBDE congeners analyzed.***

The PBDE analysis of both in-water sediment and tissue samples included eight of 209 congeners. The congeners analyzed are those typically found most frequently in the environment and should be representative of total PBDE concentrations, but lack of analysis for the full suite of chemicals presents uncertainty in total PBDE concentrations.

#### ***Evaluation of congeners with known toxicity values.***

Only PBDE congeners with published, peer reviewed toxicity values were evaluated in this risk assessment. This limited the number of congeners included in the

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quantitative analysis to four (BDE 47, BDE 99, BDE 153, BDE 209). The uncertainty associated with lack of toxicity information for PBDE congeners could potentially impact the conclusions of this risk evaluation.

***Selection of Tissue COPCs Based On Detection of An Analyte.***

The selection of PBDE COPCs was based on whether an analyte was detected in each medium or tissue type, and not based on a comparison with health-protective screening levels. There is uncertainty associated with identification of tissue COPCs based on detections alone, and this could potentially impact the conclusions of this risk evaluation for PBDEs.

***No Consideration of Background.***

PBDEs leach from products with residential, commercial, and industrial uses and have wide-spread presence in the environment. The concentrations detected in sediment and tissue were generally similar throughout the Study Area, indicating the potential for a background contribution. Per EPA guidance (2002), the contribution of background, both natural and anthropogenic, to site concentrations should be distinguished if possible. However, anthropogenic background concentrations for PBDEs have not been established for the Study Area. While risks from PBDEs were evaluated without accounting for contributions from background, it is important to recognize that background concentrations may result in unacceptable risks based on the exposure assumptions used.

## **8.07.0 SUMMARY AND CONCLUSIONS**

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This attachment presents a risk evaluation of exposure to PBDEs measured in in-water sediment and fish and shellfish tissue collected during LWG sampling events from the Study Area, upstream reach, and downtown reach.

The methods and assumptions used in this evaluation are the same as those used in the BHHRA and are presented in the text of Appendix F.

This evaluation found that cancer risks associated with exposure to PBDEs in in-water sediment and tissue consumption are orders of magnitude below the EPA target risk level of  $1 \times 10^{-6}$ . Noncancer hazards from exposures to PBDEs in in-water sediment and shellfish tissue are also below the EPA target HQ of 1. Hazards from exposures to PBDEs in fish tissue and breastmilk exceed the EPA target HQ of 1.